REVIEW | OPEN ACCESS

Medical Science

To Cite:
Thalib HI, Khan S, Saleh DS, Alshanberi AM, Alhindi YZ, Alsanosi SM. Role of Artificial Intelligence in polypharmacy and medication nonadherence in Saudi Arabia. *Medical Science* 2024; 28: e24ms3321 doi: https://doi.org/10.54905/disssi.v28i145.e24ms3321

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Peer-Review History
Received: 15 January 2024
Reviewed & Revised: 19/January/2024 to 21/March/2024
Accepted: 24 March 2024
Published: 29 March 2024

Peer-review Method
External peer-review was done through double-blind method.

Medical Science
pISSN 2321–7359; eISSN 2321–7367

DISCOVERY SCIENTIFIC SOCIETY

Role of Artificial Intelligence in polypharmacy and medication nonadherence in Saudi Arabia

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ABSTRACT

Polypharmacy and medication nonadherence are growing global challenges in healthcare, especially among the older population. The rate of both is relatively high worldwide and in Saudi Arabia, with about 50% of chronic disease patients failing to comply with their treatment regimen. These issues should be countered to improve healthcare delivery systems and quality of life. AI integration into the patient care plan may assist prevent Polypharmacy's negative consequences and encourage patients to follow their prescribed course of action. In order to provide better patient care, numerous AI initiatives have been established both domestically and outside in Saudi Arabia. For maximum use, however, the introduction of AI presents ethical and technical issues that need to be resolved. Saudi Arabia has made strides toward integrating AI into healthcare through improved rates of AI literacy and easy accessibility. To get the most out of AI, more work is necessary to get over its constraints.

Keywords: AI, Polypharmacy, medication, non-adherence, Saudi Arabia.

1. INTRODUCTION

Polymorbidity is an emerging global phenomenon among immunocompromised individuals, which has led to the rise in Polypharmacy. Several factors contribute to multiple drug intake, such as the multiple medication-promoting guidelines and the easy availability of drugs in developed countries (Pazan and Wehling, 2021). Polypharmacy refers to the concurrent usage of multiple drugs within a particular span. Though controversial, the intake of ≥5 medicines are generally categorized under Polypharmacy, whereas another approach considers the usage of 2 to 11 drugs as Polypharmacy. The lack of polypharmacy standards complicates the comparisons of adverse impacts (Halli-Tierney et al., 2019; Wang et al., 2021). The current investigations focus on hazardous and beneficial aspects and clinical outcomes of Polypharmacy in addition to the number of drugs. The growing public health concern can be categorized as simultaneous, cumulative, and continuous based on the drug's time window.

Polypharmacy can be beneficial in certain cases, but it could lead to harmful drug interactions and side effects of a drug on other concurrent diseases. It can also result in therapeutic failure in almost 50% of individuals taking four or more drugs (Guillot et al., 2020; Mair et al., 2020). Adherence, persistence, or compliance with the treatment is critical for its success. Medical adherence has emerged as a silent epidemic as WHO has reported a significantly lower (50%) adherence to chronic illnesses treatments. Approximately 21-37% of nonadherence cases are associated with preventable adverse drug impacts that negatively affect the treatment cost, efficacy, and safety. This phenomenon has been observed in various chronic conditions such as diabetes, asthma, HIV, hypertension, and rheumatic diseases (Chan et al., 2020; Lee et al., 2022). Improved treatment adherence is considered more effective than modifications in medical treatments of diseased individuals.

The initial term 'compliance' was supposed to have a negative connotation of patients' obedience to the physicians. However, the prescription is now considered a mutual decision of a physician and patient (Alsanosi et al., 2023). Therefore, the WHO has updated the definition of medical adherence to "the extent to which a person's behavior of taking medication, following a diet and lifestyle changes, corresponds with the agreed recommendations from a healthcare provider". Multifactorial medical adherence issues can be further categorized into disease, therapy, patient, economic and social, and healthcare system-related problems (Shahin et al., 2019). An in-depth understanding of nonadherence reasons is important for the identification of high-risk populations and removable potential barriers, as well as the development of individual adherence-promoting interventions.

2. GLOBAL AND LOCAL (KSA) PREVALENCE OF POLYPHARMACY

The global prevalence of Polypharmacy can range from 10% to 90% depending on the patients' age, considered definition, geographical area, and healthcare system. A study revealed that 20% of the old-age European population (70-74 years), particularly the deprived individuals, are simultaneously prescribed ≥10 drugs (Midão et al., 2021). Scotland-based investigations have revealed that the ratio of individuals simultaneously taking ≥5 medications has doubled, whereas 16.9% of the adult population was found to take 4-9 medicines. Similarly, a threefold rise has been noted in patients taking ≥10 medications from 1995 (5.8%) to 2010 (20.8%). Higher polypharmacy rates were observed in individuals with lower literacy and females. The study also depicted lower polypharmacy rates in the Western European population than in immigrants from the Middle Eastern countries (Payne, 2016; Khezrian et al., 2020).

A study in South Korea (≥90 days and ≥180 days) deduced a steady increase in polypharmacy prevalence among elderly patients reported Polypharmacy among 27.2% of the participants, which ranged from 16.4% to 60.8% in Geneva and Coimbra, respectively. Polypharmacy was found to be linked with higher comorbidities, BMI, and age (Zhang et al., 2020). A study in Saudi Arabia analyzed the profiles of 3009 patients and found Polypharmacy in 55% of individuals where, on average, 6.4 medicines were prescribed per patient. The study further noticed a linear relationship between Polypharmacy, patient's age, and comorbidity (Cho et al., 2022). AlJawadi et al., (2022) have reported the prescription of multiple drugs to 51.5% of older Saudi Arabian adults, which raised the risks in diabetic, pain, hypertension, and suggestive depression patients.

The patients from the central regions had more multiple prescriptions than patients from the Northern and Southern regions (Aljawadi et al., 2022). Another investigation reported up to 4 prescriptions in 54% and ≥ five prescriptions in 46% of participants. The prevalence of Polypharmacy has almost doubled in diabetes and hypertension patients, whereas dementia patients experienced five times the increase in Polypharmacy in comparison to the general population. A study in the Al-Ahsa region of Saudi Arabia has reported an 18% prevalence of Polypharmacy (Balkhi et al., 2021). The prevalence of Polypharmacy differs in various countries; however, the convenience of medication availability has led to a continuous increase in prescription rates.

Global and local (KSA) prevalence of medication nonadherence

A study revealed self-reported non-compliance with the treatment regimen in 19.9% of the Chinese population. Multiple factors contributed to this self-reported non-compliance, including gender, disease duration, and perception of medication adherence among patients (Alnaim et al., 2023). Approximately 60% of chronic disease patients in Singapore are medication non-adherent. The discontinuation of the medication generally happens in response to complicated regimens and side effects (Xu et al., 2020). Similarly, 30% of Indian epilepsy patients are known to not adhere to their treatment regimen due to negative effects, treatment duration, and polytherapy. An investigation in Missouri reported non-compliance in 1 in 4 hypertension patients and 1 in 3 diabetes patients, whereas age was noted to be the key influential factor (Kumar et al., 2021).

A study demonstrated that the majority (96.2%) of Saudi Arabian chronic illness patients do not adhere to treatment regimens. Medical adherence was affected by various factors such as dosage regimen, comorbidity type, and type of medication (Heflin et al., 2022). Another study reported that 48.2% of the patients stopped their medication without the permission of physicians, and forgetfulness was noted to be the main reason (60%) for non-compliance. Mobile applications were used by 38.5% of patients to track their prescriptions, whereas 50% of the patients used reminders to take ≥4 pills/day. Heart failure patients were more compliant with the treatment regimen, followed by chronic kidney disease patients. Contrarily, patients with Vitamin D deficiency most frequently missed their medication, followed by patients with hyperlipidemia (Kurdi et al., 2021).

A study in Riyadh depicted medical adherence in 81.6% of epilepsy patients (Almwled et al., 2022). Contrarily, the data of geriatric patients in Madinah-Al-Munawwara revealed poor adherence in 67.9% of patients, and only 32.1% of patients exhibited medication adherence. Forgetfulness was the most common factor of non-compliance, followed by the stopping of medication after feeling better, Polypharmacy, and concerns regarding side effects (Fadil et al., 2023). During a study in Khobar, Saudi Arabia, only one-third of the Type 2 Diabetes Mellitus patients were found compliant with the prescription. The patients with better knowledge of the disease showed 4 to 5 times more compliance with the medication regimen (AlQarni et al., 2019).

Current technologies and developmental status of healthcare in KSA

A significantly high incidence of non-communicable diseases (NCDs), such as obesity and diabetes, is one of the major issues in the Saudi Arabian healthcare system. Polypharmacy, particularly in the aging population with health complications, is another rising concern (Nobili et al., 2011). A cross-sectional study of heart failure patients in a Saudi Arabian tertiary hospital setting demonstrated a dangerously high prevalence (39.88%) of Polypharmacy. The increased Polypharmacy and medical nonadherence have urged healthcare practitioners to adopt innovative technologies (Alsultan et al., 2023). KSA is undergoing a transformative developmental phase in all sectors, including the healthcare system. The key objectives are to improve healthcare service quality at reduced cost and better access to healthcare services by improving the healthcare infrastructure, inducting novel healthcare technologies, and increasing the number of healthcare providers (Saeed et al., 2023).

3. AI-BASED HEALTHCARE TRANSFORMATION IN SAUDI VISION 2030

Saudi Arabia's "Vision 2030" encompasses a multidimensional strategy for economic and national growth. To implement this vision, a national transformation program (NTP) was launched in June 2016, with healthcare transformation among one of the eight themes (Chowdhury et al., 2021). The new model of care (MOC) is anticipated to promote public health and health awareness in society. Moreover, the model will improve health services through impartial geographical distribution, optimal coverage, digital solutions, and expanded comprehensive e-health services. It will also facilitate sustained improvement of healthcare services to achieve better satisfaction and experience of beneficiaries according to international standards (Chowdhury et al., 2021; Alkhamis and Miraj, 2021).

The role of Artificial Intelligence (AI) is rapidly expanding in the field of medicine. AI's capability of large-scale data interpretation can help in better clinical decision-making. It can revolutionize the healthcare system via more personalized measures according to the individual needs of the patients (Patel et al., 2009). Currently, AI is used to diagnose and recommend appropriate disease management steps. AI could be more autonomous in the future to perform complicated tasks such as patient triage. However, AI-associated potential risk factors should be carefully handled to ensure optimal healthcare delivery.

Prediction of adverse drug interaction

AI-developed systems can predict potential drug interactions by effectively analyzing major databases based on patient-related factors such as genetics, age, allergies, and ethnicity. These predisposing factors can facilitate the analysis of existing health status, prescribed medications, and medical history to foresee the occurrence of certain diseases (Yang and Kar, 2023). Collectively, the information could improve the decision-making regarding medication combinations to alleviate polypharmacy-linked adverse reactions, particularly in older individuals under multiple treatments for different diseases. Sema4 signal is a patient health-centered transformative product of a healthcare intelligence development company, Sema4 (Kureczka, 2020).

It employs AI, digital tools, and innovative exome-based genetic testing to reveal the genetic profile and clinical history of the patient. The information helps to evaluate and predict adverse risks of medications and enables healthcare practitioners, particularly

oncologists, to vigilantly evaluate multiple treatment options for better patient care (Donnard et al., 2014). Elsevier's Pinpoint suite provides evidence-based literature by utilizing machine learning and AI, which assist healthcare providers in considering contraindications and adverse drug interactions during treatment. Moreover, it facilitates making inclusive decisions to ensure patient safety in complicated cases (Vidhya et al., 2023).

Precise prescription for personalized treatments

AI-driven systems can effectively utilize existing databases to assist in precise, personalized alterations in medications and doses for various diseases based on the patients' profiles. This comprehensive strategy acknowledges the existing health situation of an individual, leading to patient satisfaction and acceptability (Roski et al., 2019). The luxury of personalized treatments for everyone in society could improve the overall quality of life for all social classes, which can be achieved by developing relevant AI algorithms. The AI-powered system known as IBM Watson for Oncology is specifically designed to select the best treatment regimen for cancer patients (Somashekhar et al., 2018). The database of this system includes all the updated literature, similar patient records, and clinical trial results to assist oncologists and patients in adopting the optimum treatment procedure among various complicated options while considering the associated factors (Liu et al., 2018).

Adherence strategies and continuous monitoring

AI tools can conveniently improve medication adherence by reshaping the previous approaches according to the patient's preferences and behaviors. AI can also suggest personalized adherence options, including educational materials, adaptive schedules for dosing, and reminders (Bohlmann et al., 2021; Al-Sharo et al., 2023; Nordin et al., 2024). AiCure is an AI-based interactive mobile app that monitors the patient and confirms his medications as prescribed. It employs facial recognition and a mobile phone camera to visually confirm a patient's medication intake and transmits the feedback to healthcare providers. Moreover, the AiCure app alerts the patient through personalized reminders to timely take the prescribed drug and provides educational interactive videos for proper intake of the medication (Bain et al., 2017; Xu et al., 2021). The app also ensures the patient's constant monitoring and medical adherence while keeping the doctor constantly informed for timely amendments in doses and medication.

The interactive features of this app significantly improve patient's adherence to the prescribed dosages and medication (Verma and Naaz, 2022). A similar app, "Tadawi", has been developed in Saudi Arabia that sends constant personalized reminders and dosage alerts to users for enhanced medical adherence (Saeed et al., 2023). The scope of this app is still limited, but future AI tools can incorporate the notifications for the patient's healthcare team further. Sehhaty Wa Daghty, an iPhone-linked Arabic health app, monitors blood pressure, food consumption, and physical activity. This app mainly focuses on developing a mobile phone-based self-monitoring of HTN to achieve improved fitness and health levels among Saudi adults (Alzahrani et al., 2023).

Sustainable medical adherence can be attained by educating patients about adverse drug reactions and enhancing awareness regarding medication adherence. The interactive AI-assisted tools can also answer the patient's queries in a user-friendly manner (Liu and Xiao, 2021; Upadhyay & Gupta, 2023). AI-based Your.MD healthcare assistant offers personalized advice and information regarding potential side effects and benefits of medication adherence. This user-friendly platform can be operated through a mobile application or surface web. It has significantly contributed to enhancing the community's awareness and scientific knowledge of medication adherence (Xu et al., 2021; Bekbolatova et al., 2024). Sehhaty app, developed by the government of Saudi Arabia, offers various healthcare services such as telemedicine, appointment booking, and interaction with health providers. It has also helped to enhance health awareness among the Saudi Arabian population (Alkhalifah et al., 2022).

4. PROSPECTS AND CHALLENGES

Despite the revolutionary AI potential in patient care through the mitigation of complex polypharmacy impacts and enhancing medical adherence, there are various ethical, technical, and legal challenges associated with its large-scale applications. The development of a broad-range AI program that can integrate into multiple healthcare systems with convenient utility for patients and healthcare providers is a complicated task (Bekbolatova et al., 2024). It requires extensive medical and personal data of numerous variable parameters for better polypharmacy management without affecting the patient's treatment. The induction of AI systems could be

limited by the existing healthcare infrastructures' data processing and storage potential. The extent of AI integration and education through government curricula could determine its level of applicability (Paul et al., 2021).

Quality-independent AI data might lead to discriminatory results against minority and marginalized groups, whereas inaccurate, missing, and poor data could compromise patient safety by negatively impacting AI algorithms. Moreover, AI algorithms (big data analytics and machine learning) require sensitive medical and personal data of the patients, which could raise questions regarding patient anonymity, confidentiality, and information safety (Bouhouita-Guermech et al., 2023; Chen et al., 2023). Therefore, issues related to patient consent and privacy must be addressed through data owner identification and legal and ethical considerations. The legislation should also be carried out to ensure the accountability of AI developers, program owners, and healthcare providers in handling medical accidents (Paul et al., 2021).

Saudi Arabian Vision 2030 anticipates embracing and integrating AI at all levels of patient care. Recent efforts have focused on enhancing AI literacy through e-learning and aiding healthcare professionals in the multidimensional diagnosis process. This article highlights the characteristics of polypharmacy and medical adherence issues in Saudi Arabia, which can be tackled by effective AI induction in pharmacy (Al-Jehani et al., 2021). Current investigations should focus on overcoming the AI program-associated limitations while concurrently exploring diverse utilities of AI- platforms for improved patient treatments. For instance, have reported a high efficiency of AI integrations for better medical adherence in non-communicable disease patients (Vora et al., 2023).

5. CONCLUSION

Polypharmacy and nonadherence are growing global challenges in healthcare, especially among the older population. The polypharmacy rate is quite high in Saudi Arabia, and 50% of chronic disease patients fail to comply with their treatment regimen. These issues should be countered to improve healthcare delivery systems and quality of life. AI incorporation into the patient care plan could help avoid the adverse effects of Polypharmacy and promote patient adherence to the treatment plan. Several AI programs have been developed internationally and locally in Saudi Arabia for better patient care. However, the induction of AI raises technical and ethical concerns that should be solved for its optimum applicability. Saudi Arabia has taken progressive steps to promote AI integration in all aspects of healthcare through enhanced AI literacy rates and convenient accessibility. However, further efforts are needed to overcome AI-posed limitations for maximum benefits.

Author Contributions

Details of contribution of each author regards manuscript work & production are all equal.

Ethical approval

The study did not need an ethical approval as it is a review.

Informed consent

Not applicable.

Funding

This study has not received any external funding.

Conflict of interest

The authors declare that there is no conflict of interests.

Data and materials availability

All data sets collected during this study are available upon reasonable request from the corresponding author.

REFERENCES

1. Aljawadi MH, Khoja AT, Alaboud NM, AlEnazi ME, Al-Shammari SA, Khoja TA, AlMuqbil MS, Alsheikh AM, Alwhaibi M. Prevalence of Polypharmacy and Factors Associated with it Among Saudi Older Adults–Results from the Saudi National Survey for Elderly Health (SNSEH). Saudi Pharm J 2022; 30(3):230-236. doi: 10.1016/j.jsps.2022.01.003
2. Al-Jehani NB, Hawsawi ZA, Radwan NE, Farouk MA. Development of artificial intelligence techniques in Saudi Arabia: the impact on COVID-19 pandemic. Literature review. J Eng Sci Technol 2021; 16(6):4530-4547.
3. Alkhalifah JM, Seddiq W, Alshehri BF, Alhaluli AH, Alessa MM, Alsulais NM. The role of the COVID-19 pandemic in expediting digital health-care transformation: Saudi Arabia's experience. Inform Med Unlocked 2022; 33:101097. doi: 10.1016/j.imu.2022.101097
4. Alkhamis A, Miraj SA. Access to health care in Saudi Arabia: development in the context of vision 2030. In Handbook of healthcare in the Arab world 2021; 1629-1660. Cham: Springer International Publishing. doi: 10.1007/978-3-030-36811-1_83
5. Almwled AS, Almuhaydili AO, Altamimi SM, Alzahrani MA, Alnahdi RK, Almotairi SB, Aljafen BN, Alosaimi FD. Prevalence and biopsychosocial factors associated with treatment adherence among people with epilepsy in a tertiary care hospital in Riyadh, Saudi Arabia. Nurosci (Riyadh) 2022; 27(2):94-103. doi: 10.17712/nsj.2022.2.20210142
6. Alnaim AA, Almuhanna SM, AlHussain AK, Alkhteeb NA, Alabdullah ZA. Prevalence of polypharmacy and medication-related quality of life among adult patients in Al-Ahsa, Saudi Arabia. J Med Life 2023; 16(9):1415-1420. doi: 10.25122%2Fjml-2023-0101
7. AlQarni K, Naqvi AA, Ghori SA, Haseeb A, Raafat M, Jamshed S. Assessment of medication adherence in Saudi patients with Type II diabetes mellitus in Khobar City, Saudi Arabia. Front Pharmacol 2019; 10:1306. doi: 10.3389/fphar.2019.01306
8. Alsanosi SM, Mousa AH, Ahmadini HA, Qadhi RS, Ikram N, Felemban AH, Alqashqri HS, Hariri NH, Alhindi YZ, Ayoub N. Polypharmacy among patients with hypertension attending primary healthcare centres. Ann Med Surg (Lond) 2023; 85(6):2545-2549. doi: 10.1097/MS9.0000000000000818
9. Al-Sharo Y, Abu-Jassar A, Lyashenko V, Yevsieiev V, Maksymova S. A Robo-hand prototype design gripping device within the framework of sustainable development. Indian J. Eng. 2023; 20:e37ije1673. doi: 10.54905/disssi.v20i54.e37ije1673
10. Alsultan MM, Alamer R, Alammar F, Alzlaiq W, Alahmari AK, Almalki ZS, Alqarni F, Alshayban DM, Alotaibi FM, Asiri IM, Alsultan F, Kurdi SM, Almalki BA. Prevalence of polypharmacy in heart failure patients: A retrospective cross-sectional study in a tertiary hospital in Saudi Arabia. Saudi Pharm J 2023; 31(12):101875. doi: 10.1016/j.jsps.2023.101875
11. Alzahrani A, Gay V, Alturki R. Enabled Artificial Intelligence (AI) to Develop Sehhaty Wa Daghty App of Self-Management for Saudi Patients with Hypertension: A Qualitative Study. Information 2023; 14(6):334. doi: 10.3390/info14060334
12. Bain EE, Shafner L, Walling DP, Othman AA, Chuang-Stein C, Hinkle J, Hanina A. Use of a Novel Artificial Intelligence Platform on Mobile Devices to Assess Dosing Compliance in a Phase 2 Clinical Trial in Subjects with Schizophrenia. JMIR Mhealth Uhealth 2017; 5(2):e18. doi: 10.2196/mhealth.7030
13. Balkhi B, AlQahtani N, Alwhaibi M, Alshammari TM, Alhawassi TM, Mahmoud MA, Almetwazi M, Ata S, Basyoni M, Aljadhey H. Prevalence and Factors Associated with Polypharmacy Use Among Adult Patients in Saudi Arabia. J Patient Saf 2021; 17(8):e1119-e1124. doi: 10.1097/PTS.0000000000000439
14. Bekbolatova M, Mayer J, Ong CW, Toma M. Transformative Potential of AI in Healthcare: Definitions, Applications, and Navigating the Ethical Landscape and Public Perspectives. Healthcare (Basel) 2024; 12(2):125. doi: 10.3390/healthcare12020125
15. Bohlmann A, Mostafa J, Kumar M. Machine Learning and Medication Adherence: Scoping Review. JMIRx Med 2021; 2(4):e26993. doi: 10.2196/26993
16. Bouhouita-Guermech S, Gogognon P, Bélisle-Pipon JC. Specific challenges posed by artificial intelligence in research ethics. Front Artif Intell 2023; 6. doi: 10.3389%2Ffrai.2023.1149082
17. Chan AH, Horne R, Hankins M, Chisari C. The Medication Adherence Report Scale: A measurement tool for eliciting patients' reports of nonadherence. Br J Clin Pharmacol 2020; 86(7):1281-1288. doi: 10.1111/bcp.14193
18. Chen P, Wu L, Wang L. AI fairness in data management and analytics: A review on challenges, methodologies and applications. Appl Sci 2023; 13(18):10258. doi: 10.3390/app131810258
19. Cho HJ, Kim DS. Aging and the Prevalence of Polypharmacy and Hyper-Polypharmacy Among Older Adults in South Korea: A National Retrospective Study During 2010-2019.

Front Pharmacol 2022; 13:866318. doi: 10.3389/fphar.2022.866318
20. Chowdhury S, Mok D, Leenen L. Transformation of health care and the new model of care in Saudi Arabia: Kingdom's Vision 2030. J Med Life 2021; 14(3):347-354. doi: 10.25122%2Fjml-2021-0070
21. Donnard E, Asprino PF, Correa BR, Bettoni F, Koyama FC, Navarro FC, Perez RO, Mariadason J, Sieber OM, Strausberg RL, Simpson AJ, Jardim DL, Reis LF, Parmigiani RB, Galante PA, Camargo AA. Mutational analysis of genes coding for cell surface proteins in colorectal cancer cell lines reveal novel altered pathways, druggable mutations and mutated epitopes for targeted therapy. Oncotarget 2014; 5(19):9199-213. doi: 10.18632%2Foncotarget.2374
22. Fadil HA, Sammman WA, Elshafie RM. Prevalence of Nonadherence to Medications among Geriatric Patients in Al-Madinah Al-Munawara City's Hospitals, Kingdom of Saudi Arabia. Int J Clin Pract 2023; 2023:3312310. doi: 10.1155/2023/3312310
23. Guillot J, Maumus-Robert S, Bezin J. Polypharmacy: a general review of definitions, descriptions and determinants. Therapie 2020; 75(5):407-416. doi: 10.1016/j.therap.2019.10.001
24. Halli-Tierney AD, Scarbrough C, Carroll D. Polypharmacy: evaluating risks and deprescribing. Am Fam Physician 2019; 100(1):32-38.
25. Heflin C, Hodges L, Ojinnaka CO, Arteaga I. Hypertension, Diabetes and Medication Adherence among the Older Supplemental Nutritional Assistance Program Population. J Appl Gerontol 2022; 41(3):780-787. doi: 10.1177/07334648211022493
26. Khezrian M, McNeil CJ, Murray AD, Myint PK. An overview of prevalence, determinants and health outcomes of polypharmacy. Ther Adv Drug Saf 2020; 11:2042098620933741. doi: 10.1177/2042098620933741
27. Kumar S, Singh MB, Kumar A, Srivastava MP, Goyal V. Medication adherence in Indian epilepsy patients. Ann Indian Acad Neurol 2021; 24(4):501-505. doi: 10.4103/aian.AIAN_925_20
28. Kurdi S, Albannay R, Alsinan Z, Islam A. Evaluation of medication adherence among patients with chronic diseases in Saudi Arabia. Int J Clin Pract 2021; 75(7):e14253. doi: 10.1111/ijcp.14253
29. Kureczka JE. Getting the word out: Public Relations strategies to support biotechnology business goals. Biotechnol Entrep 2020; 513-524. doi: 10.1016/B978-0-12-815585-1.00034-6
30. Lee EK, Poon P, Yip BH, Bo Y, Zhu MT, Yu CP, Ngai AC, Wong MCS, Wong SYS. Global Burden, Regional Differences, Trends, and Health Consequences of Medication Nonadherence for Hypertension During 2010 to 2020: A Meta-Analysis Involving 27 Million Patients. J Am Heart Assoc 2022; 11(17):e026582. doi: 10.1161/JAHA.122.026582
31. Liu C, Liu X, Wu F, Xie M, Feng Y, Hu C. Using Artificial Intelligence (Watson for Oncology) for Treatment Recommendations Amongst Chinese Patients with Lung Cancer: Feasibility Study. J Med Internet Res 2018; 20(9):e11087. doi: 10.2196/11087
32. Liu T, Xiao X. A framework of AI-based approaches to improving eHealth literacy and combating infodemic. Front Public Health 2021; 9:755808. doi: 10.3389/fpubh.2021.755808
33. Mair A, Wilson M, Dreischulte T. Addressing the challenge of polypharmacy. Annu Rev Pharmacol Toxicol 2020; 60:661-681. doi: 10.1146/annurev-pharmtox-010919-023508
34. Midão L, Brochado P, Almada M, Duarte M, Paúl C, Costa E. Frailty status and polypharmacy predict all-cause mortality in community dwelling older adults in Europe. Int J Environ Res Public Health 2021; 18(7):3580. doi: 10.3390/ijerph18073580
35. Nobili A, Garattini S, Mannucci PM. Multiple diseases and polypharmacy in the elderly: challenges for the internist of the third millennium. J Comorb 2011; 1:28-44. doi: 10.15256/joc.2011.1.4
36. Nordin MI, Ishak MK, Din AS, Seman MTA. Intelligent pressure and temperature sensor algorithm for diabetic patient monitoring: An IoT approach. Indian J. Eng. 2024; 21:e2ije1676
37. Patel VL, Shortliffe EH, Stefanelli M, Szolovits P, Berthold MR, Bellazzi R, Abu-Hanna A. The coming of age of artificial intelligence in medicine. Artif Intell Med 2009; 46(1):5-17. doi: 10.1016/j.artmed.2008.07.017
38. Paul D, Sanap G, Shenoy S, Kalyane D, Kalia K, Tekade RK. Artificial intelligence in drug discovery and development. Drug Discov Today 2021; 26(1):80-93. doi: 10.1016%2Fj.drudis.2020.10.010
39. Payne RA. The epidemiology of polypharmacy. Clin Med (Lond) 2016; 16(5):465-469. doi: 10.7861%2Fclinmedicine.16-5-465
40. Pazan F, Wehling M. Polypharmacy in older adults: a narrative review of definitions, epidemiology and consequences. Eur Geriatr Med 2021; 12(3):443-452. doi: 10.1007/s41999-021-00479-3
41. Roski J, Hamilton BA, Chapman W, Heffner J, Trivedi R, Del Fiol G, Kukafka R, Bleicher P, Estiri H, Klann J, Pierce J. How artificial intelligence is changing health and healthcare. Artificial intelligence in health care: The hope, the hype, the

promise, the peril. National Academy of Medicine 2019; 59–88.
42. Saeed A, Saeed AB, AlAhmri FA. Saudi Arabia Health Systems: Challenging and Future Transformations with Artificial Intelligence. Cureus 2023; 15(4):e37826. doi: 10.7759/cureus.37826
43. Shahin W, Kennedy GA, Stupans I. The impact of personal and cultural beliefs on medication adherence of patients with chronic illnesses: a systematic review. Patient Prefer Adherence 2019; 13:1019-1035. doi: 10.2147/PPA.S212046
44. Somashekhar SP, Sepúlveda MJ, Puglielli S, Norden AD, Shortliffe EH, Kumar CR, Rauthan A, Kumar NA, Patil P, Rhee K, Ramya Y. Watson for Oncology and breast cancer treatment recommendations: agreement with an expert multidisciplinary tumor board. Ann Oncol 2018; 29(2):418-423. doi: 10.1093/annonc/mdx781
45. Upadhyay S, Gupta YK. Prediction of diabetes in adults using supervised machine learning model. Indian J. Eng. 2023; 20:e26ije1657. doi: 10.54905/disssi/v20i53/e26ije1657
46. Verma A, Naaz I. Prospects and Difficulties of Artificial Intelligence (AI) Implementations in Naturopathy. Artif Intell Innov Healthcare Inform 2022; 309-327. doi: 10.1007/978-3-030-96569-3_15
47. Vidhya KS, Sultana A, Kumar MN, Rangareddy H. Artificial intelligence's impact on drug discovery and development from bench to bedside. Cureus 2023; 15(10):e47486. doi: 10.7759/cureus.47486
48. Vora LK, Gholap AD, Jetha K, Thakur RR, Solanki HK, Chavda VP. Artificial Intelligence in Pharmaceutical Technology and Drug Delivery Design. Pharm 2023; 15(7):1916. doi: 10.3390/pharmaceutics15071916
49. Wang KN, Tan ECK, Ilomäki J, Gilmartin-Thomas JFM, Sluggett JK, Cooper T, Robson L, Bell JS. What is the Best Definition of Polypharmacy for Predicting Falls, Hospitalizations, and Mortality in Long-Term Care Facilities? J Am Med Dir Assoc 2021; 22(2):470-471. doi: 10.2196/27850
50. Xu L, Sanders L, Li K, Chow JCL. Chatbot for Health Care and Oncology Applications Using Artificial Intelligence and Machine Learning: Systematic Review. JMIR cancer 2021; 7(4): e27850. doi: 10.2196/27850
51. Xu N, Xie S, Chen Y, Li J, Sun L. Factors influencing medication non-adherence among Chinese older adults with diabetes mellitus. Int J Environ Res Public Health 2020; 17(17):6012. doi: 10.3390/ijerph17176012
52. Yang S, Kar S. Application of artificial intelligence and machine learning in early detection of adverse drug reactions (ADRs) and drug-induced toxicity. Artif Intell Chem 2023; 1(2):100011. doi: 10.1016/j.aichem.2023.100011
53. Zhang N, Sundquist J, Sundquist K, Ji J. An Increasing Trend in the Prevalence of Polypharmacy in Sweden: A Nationwide Register-Based Study. Front Pharmacol 2020; 11:326. doi: 10.3389/fphar.2020.00326